Exploitation and Optimization of Reservoir Performance in Hunton Formation, Oklahoma

QUARTERLY TECHNICAL PROGRESS REPORT

Submitted by

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Contract Date: March 7, 2000

Completion Date: June 30, 2007

Reporting Period: October 1 – December 31, 2006

Date Issued: January 31, 2007

DOE Contract No. DE-FC26-00NT15125

Prepared for

U.S. Department of Energy
Assistant Secretary for Fossil Energy

Contracting Officer's Representative:

Mr. Purna Halder
U.S. Department of Energy
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Abstract

West Carney field – one of the newest fields discovered in Oklahoma – exhibits many unique production characteristics. These characteristics include:

1) decreasing water-oil ratio;
2) decreasing gas-oil ratio followed by an increase;
3) poor prediction capability of the reserves based on the log data; and
4) low geological connectivity but high hydrodynamic connectivity.

The purpose of this investigation is to understand the principal mechanisms affecting the production, and propose methods by which we can extend the phenomenon to other fields with similar characteristics.

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Executive Summary

In this period, we developed a material balance technique to understand the behavior of Hunton reservoir. The method assumes that the reservoir originally contains oil and water and as the reservoir pressure depletes, the released gas from the solution is produced from the wells. Using the gas and production data from one of the Hunton reservoir fields (Vinco Field), we were able to validate our methodology. Through history matching process, we were able to predict the relative permeability ratio (k_{rg}/k_{rw}) as a function of gas saturation, and by extrapolating this curve, we could also predict the future performance of the reservoir. The predicted future performance indicates that the recovery process is inefficient due to water production and the recovery can be substantially improved if we reduce the reservoir pressure substantially.

Experimental

No new experimental data were conducted.

Results and Discussion

Engineering and Geological Analysis

Geraldo Ramos and Mohan Kelkar, The University of Tulsa

We conducted a revised material balance analysis for the Carney area to understand the basic differences of the dewatering project compared to a conventional gas reservoir. We present results of one area of Carney field in this report.

The basic material balance equation for oil reservoirs is easy to establish. The details are provided in Appendix A. In most of the Hunton dewatering projects, we make the key assumption that the reservoir originally contains oil with dissolved gas. If the initial oil has high enough saturation, oil will become mobile and produce at the wells. Otherwise, only the released gas from the solution would be produced. In effect, the wells will only produce gas – implying that the reservoir is a gas reservoir – although the reservoir originally contains oil and water.

The material balance equation was used in two different ways to validate the equation. First, using equations A-11 and A-13, we calculated water saturation based on cumulative production and compared to water saturations from those two equations. If our material balance equation is correct, we expect that those two values will match. To validate our method, we used the data from Vinco field. The details of the geological information, as well as production information, are provided in Table 1 and Table 2.

Table 1: Geological Data

Porosity		0.2
Area	Acres	3731
Thickness	ft	30
API		40
Temperature	oF	110
Swi		0.7
Gas sp.grav		0.8
Mole Fr	CO2	0
Mole Fr	H2S	0
Water	ppm	0
Psep	Psia	100
Tsep	oF	100

Table 2: Past Production Data

PBH	Wp	GP
Psia	STB	MSCF
1197	0	0
1119	3189036	317479
1111	3712643	409571
974	5341304	710135
974	7665925	1137314
923	7991728	12113978
840.8	13754272	3022173

Using the data provided above, we calculated the water saturation using both equations and calculated the error. To examine the sensitivity of fluid properties on our ability to correctly predict the water saturation, we used different equations for gas-oil ratios. The results of this analysis are shown in Table 3.

Table 3: Statistical error computed from different correlations

Correlation	% AE	Std.Dev.	% AAE	Std.Dev.
Glaso	-3.47	3.33	3.47	3.33
Standing	-2.22	2.57	2.22	2.57
P-Farshad	-3.91	3.63	3.91	3.63
V-Beggs	-2.67	2.82	2.67	2.82
Marhoun	-2.50	2.76	2.50	2.76
Katoamodjo	-2.58	2.75	2.58	2.75
Lasater	-2.75	2.86	2.75	2.86

Based on the results above, Standing's correlation provides the smallest error in terms of comparing the water saturations using the two equations.

We also used a material balance equation as a prediction tool. This required us to first do history matching of existing production data. Using the material balance equations provided in Appendix A, we calculated instantaneous GOR based on the production data and, for only gas water production, calculated relative permeability ratio using the following two equations:

$$GWR = \frac{k_{rg}}{k_{rw}} \frac{B_w}{B_g} \frac{\mu_w}{\mu_g} \qquad (1)$$

$$\frac{k_{rg}}{k_{rw}} = (GWR)\left(\frac{\mu_g B_g}{\mu_w B_w}\right) \qquad (2)$$

Using the relative permeability values based on the historical data, we fitted the ratio with an empirical fit as shown in Figure 1:

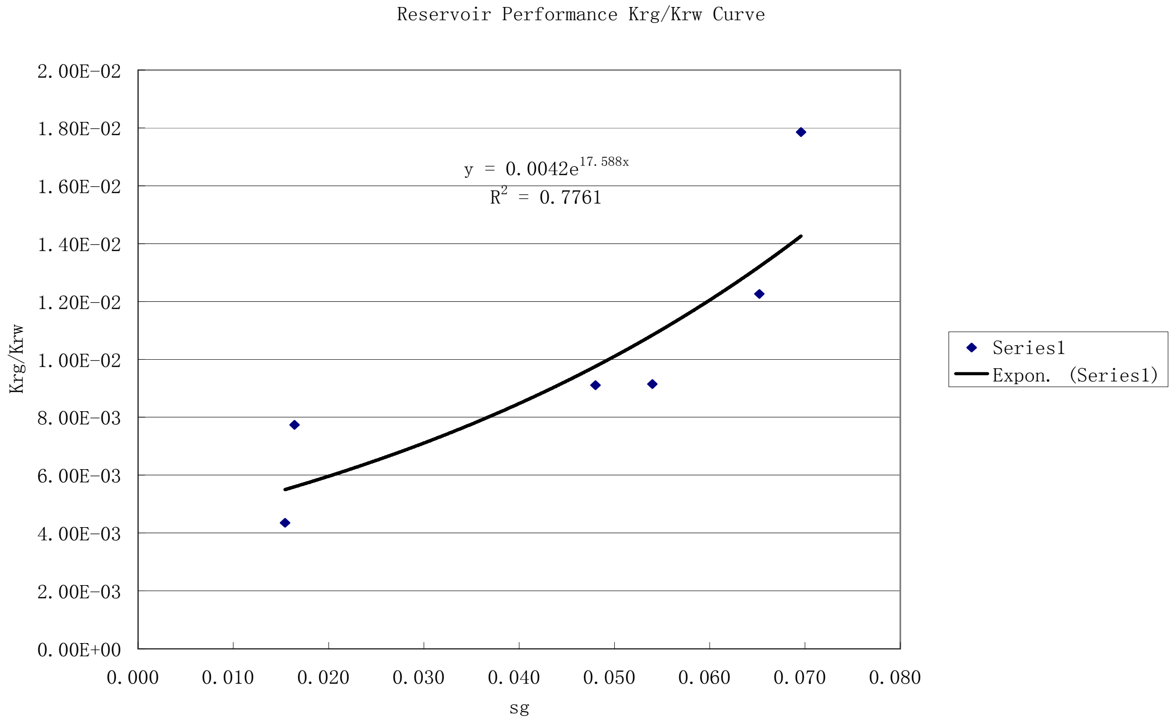

Figure 1: Reservoir performance curve

We use exponential fit for the data so that by using the same equation, we can predict the future performance of the reservoir. We followed the procedure to predict the future performance as given in Appendix A. We took small decrements of pressure and calculated incremental gas and water production using GWR values as predicted by the empirical equation. Figure 2 shows the plot of gas produced as a function of pressure using this methodology:

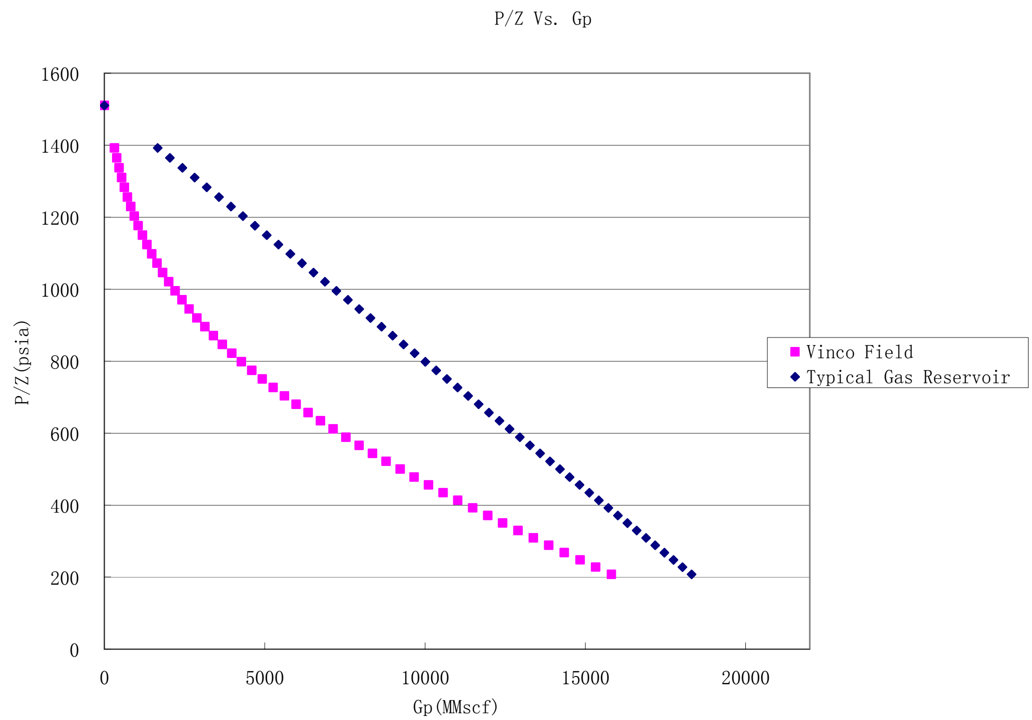

Figure 2: Plot of gas production from model and typical gas reservoir

As shown in the above graph, we do not have a traditional straight line on the p/z plot. If this had been a gas reservoir, we would expect to see a straight line. Instead, we see a concave behavior. In other words, dewatering reservoirs are less efficient than traditional gas depletion reservoirs. This is not surprising since part of the energy is used to produce water in the dewatering project. As a result, for a given abandonment pressure, the recovery of gas is going to be low in dewatered reservoirs compared to traditional gas reservoirs. This difference is very important. If we intend to recover more gas from these reservoirs, we need to find a way by which we can reduce the reservoir pressure substantially. This requires reducing the bottom hole flowing pressure substantially. This may not be possible unless we come up with a procedure such that the produced water is lifted efficiently. We intend to work on this particular problem and provide some results in the next report.

Nomenclature

A	=	Section area, acres
Bg	=	Gas formation volume factor, bbl/scf
Bgi	=	Initial gas formation volume factor, bbl/scf
Bo	=	Oil formation volume factor, bbl/stb
Boi	=	Initial oil formation volume factor, bbl/stb
G	=	Initial gas in place, Mscf
Gp	=	Cumulative gas production, Mscf
Gp1	=	Cumulative gas produced at previous pressure, Mscf
$(GWR)_{avg}$	=	Average gas water ratio, Mscf/stb
h	=	Thickness, ft
krg	=	Gas relative permeability, md
krw	=	Water relative permeability, md
N	=	Oil initially in place, stb
Np	=	Cumulative oil production, stb
P	=	Reservoir pressure, psia
Pi	=	Initial reservoir pressure, psia
Rs	=	Gas oil ratio, scf/stb
Rsi	=	Initial gas oil ratio, scf/stb
Rp	=	Cumulative gas oil ratio, scf/stb
Sg	=	Gas saturation
Sgi	=	Initial gas saturation
So	=	Oil saturation
Soi	=	Initial oil saturation
Sw	=	Water saturation
Swi	=	Initial water saturation
Z	=	Gas compressibility factor
Zi	=	Initial gas compressibility factor
μ	=	viscosity, cp
ϕ	=	Porosity

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Appendix A

$$OIIP = N = \frac{7758Ah\phi(1-S_{wi})}{B_{oi}} \quad \text{(A.1)}$$

$$GIIP = G = \frac{7758Ah\phi(1-S_{wi})R_{si}}{B_{oi}} \quad \text{(A.2)}$$

$$WIIP = W = \frac{7758Ah\phi S_{wi}}{B_{wi}} \quad \text{(A.3)}$$

$$N_p\left[B_o + \left(R_p - R_s\right)B_g\right] + W_pB_w = N\left[\left(B_o - B_{oi}\right) + \left(R_{si} - R_s\right)B_g\right] \quad \text{(A.4)}$$

$$N_p = N_{p1} + \Delta N_p \quad \text{(A.5)}$$

$$W_p = W_{p1} + \Delta W_p \quad \text{(A.6)}$$

$$G_p = G_{p1} + \Delta G_p \quad \text{(A.7)}$$

$$\left(GWR\right)_{avg} \cong \frac{\Delta G_p}{\Delta W_p} \quad \text{(A.8)}$$

$$N_P R_P = G_P \quad \text{(A.9)}$$

$$S_o = \left(1 - S_{wi}\right)\left(1 - \frac{N_p}{N}\right)\frac{B_o}{B_{oi}} \quad \text{(A.10)}$$

$$S_W = \left[S_{wi} - \frac{W_P\left(1 - S_{wi}\right)B_{wi}}{NB_{oi}}\right]\frac{B_w}{B_{wi}} \quad \text{(A.11)}$$

$$S_g = \left[\left(R_{si} - R_s\right) - \frac{N_P}{N}\left(R_P - R_S\right)\right]\frac{B_g}{B_{oi}}\left(1 - S_{wi}\right) \quad \text{(A.12)}$$

$$S_w = 1 - S_o - S_g \quad \text{(A.13)}$$

$$\frac{P}{Z} = \frac{P_i}{Z_i}\left(1 - \frac{G_p}{G}\right) \quad \text{(A.14)}$$

$$\left(GWR\right)_{avg} = \left(\frac{GWR_1 + GWR_2}{2}\right) \quad \text{(A.15)}$$

Technology Transfer

No technology transfer activity was conducted.

Conclusions

We developed a material balance equation to understand the depletion mechanism for Hunton reservoir. We validated our methodology by using one of the Hunton fields. The results indicate that the proposed material balance is reasonable. Using our approach, we were able to predict the future performance of the reservoir. The results of the future performance indicate the need for developing a better methodology for lifting the water from the well to maintain low bottom hole pressure. .